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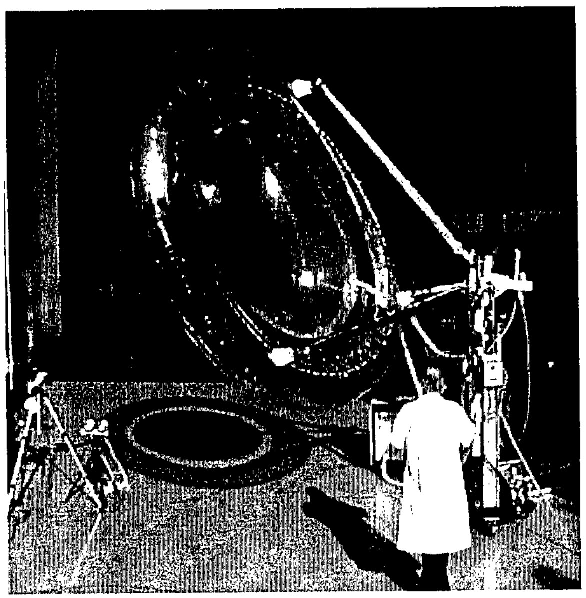
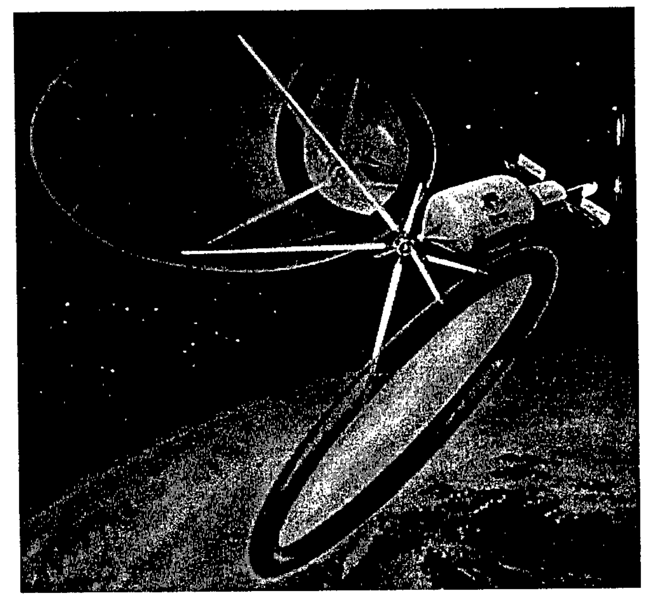
AIAA Space Technology Conference and Exposition

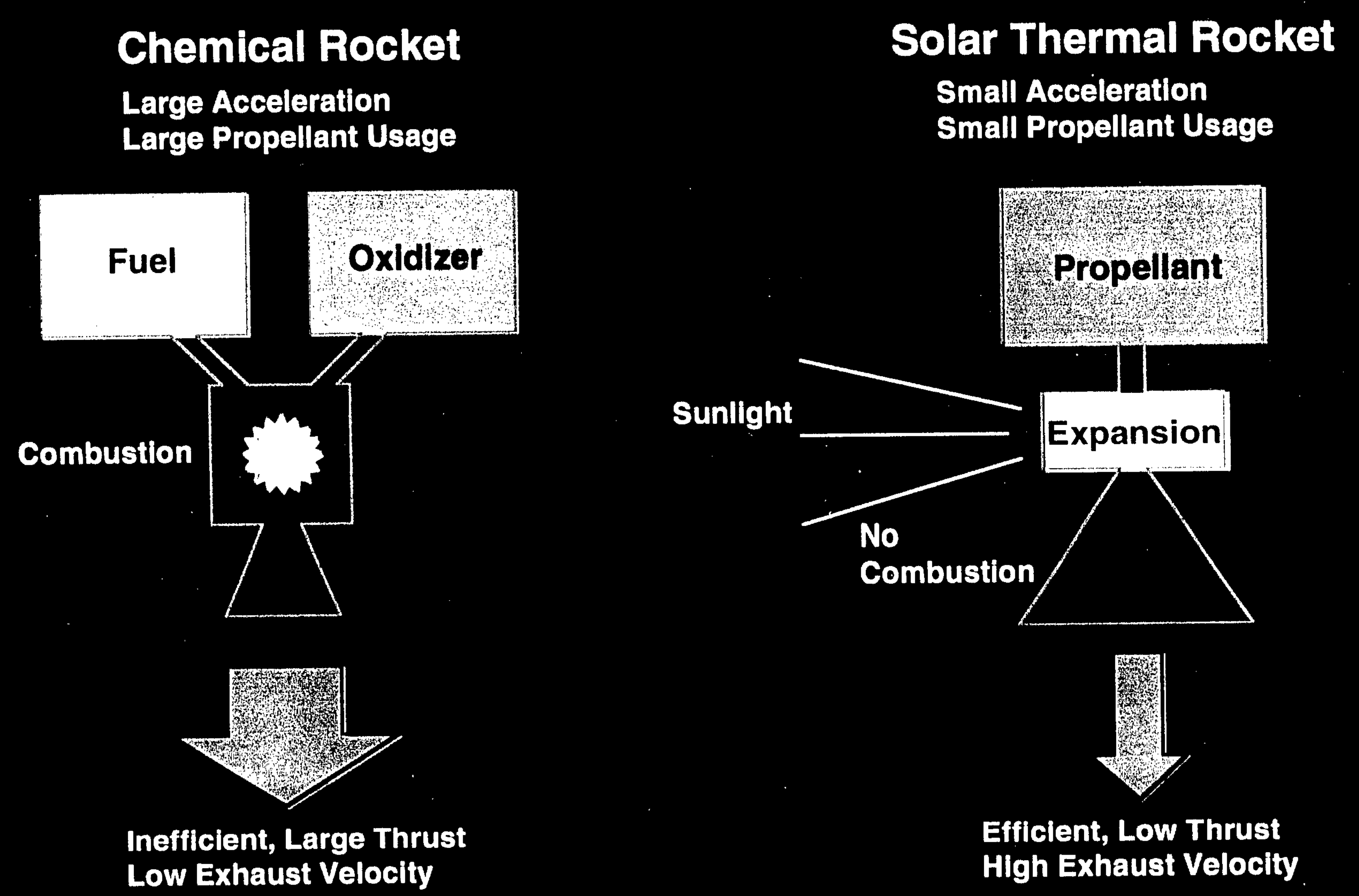


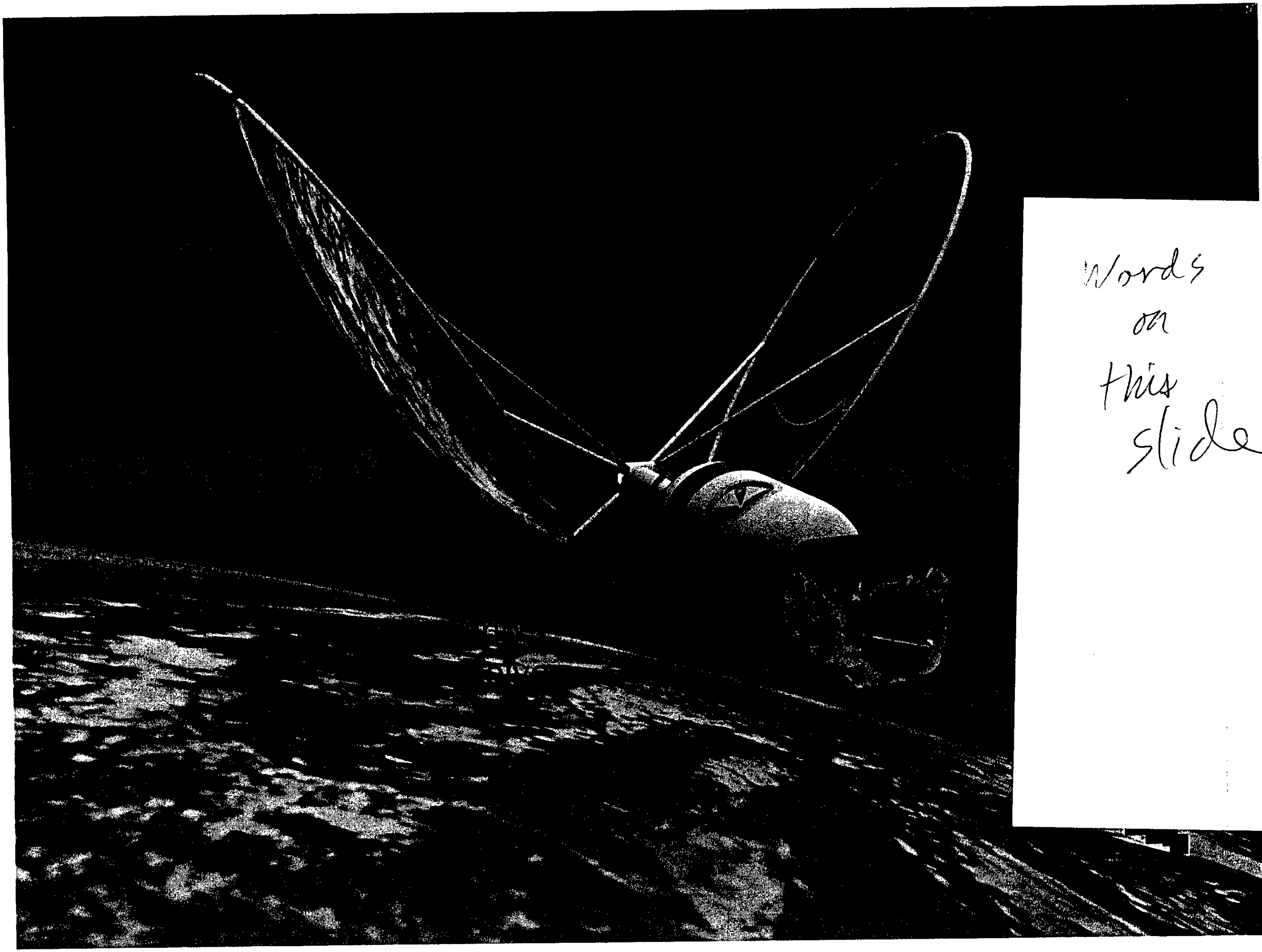


SOLAR-THERMAL PROPULSION

Dr. Michael Holmes, AFRL/PRRS

Solar Thermal & Chemical Propulsion Comparison



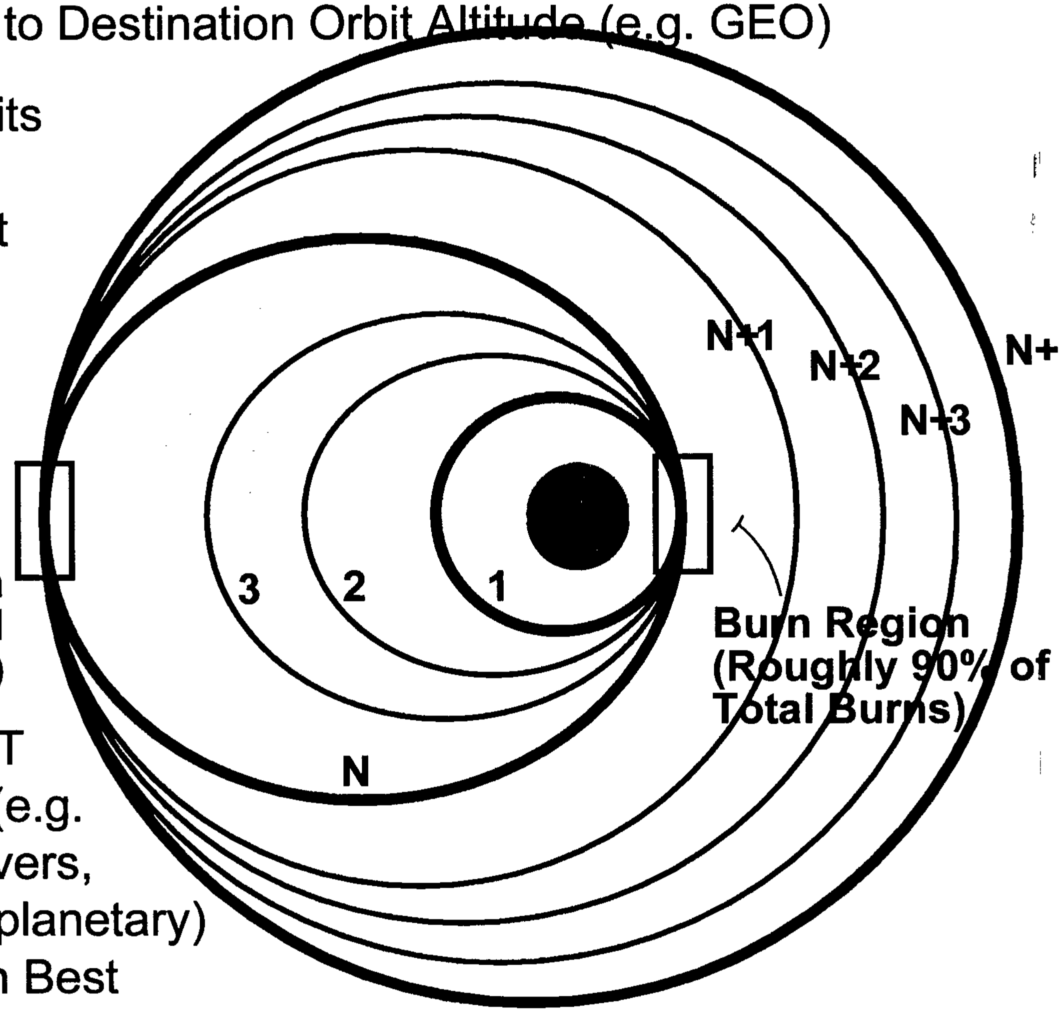


Words on this slide?

Solar Thermal Propulsion Orbit Transfer Scenario

- Solar Thermal OTV to LEO by Ground Launch
- N Perigee Burns to Raise Apogee to Destination Orbit Altitude (e.g. GTO)
- M Apogee Burns to Raise Perigee to Destination Orbit Altitude (e.g. GEO)

- Trip Time = Sum of Periods of Orbits
- Higher Thrust Gives Fewer Orbits
- Longer Burns Give More Orbits but Less Delta V
- Takes a Month or Two for Solar Thermal from LEO to GEO
- Takes Many Months for Electric Propulsion from LEO to GEO



- Many Other Orbital Maneuvers NOT Limited by Orbit Period or Number (e.g. Station Keeping, High Orbit maneuvers, Orbit Control, Orbit Tweaking, Interplanetary)
- High Isp Electric Propulsion is Then Best

SOLAR PROPULSION PHASE I
Program + GOALS

~~Program~~ GOALS	BASELINE	PHASE I GOAL	PHASE I ROLLUP
Isp	720 sec	792 sec 10 %	792 sec 10 %
Mass Fraction	.66	.696	.696
Dry Mass Reduction		15%	15%

Mission : LEO to GEO (250nm at 28deg) ~30day

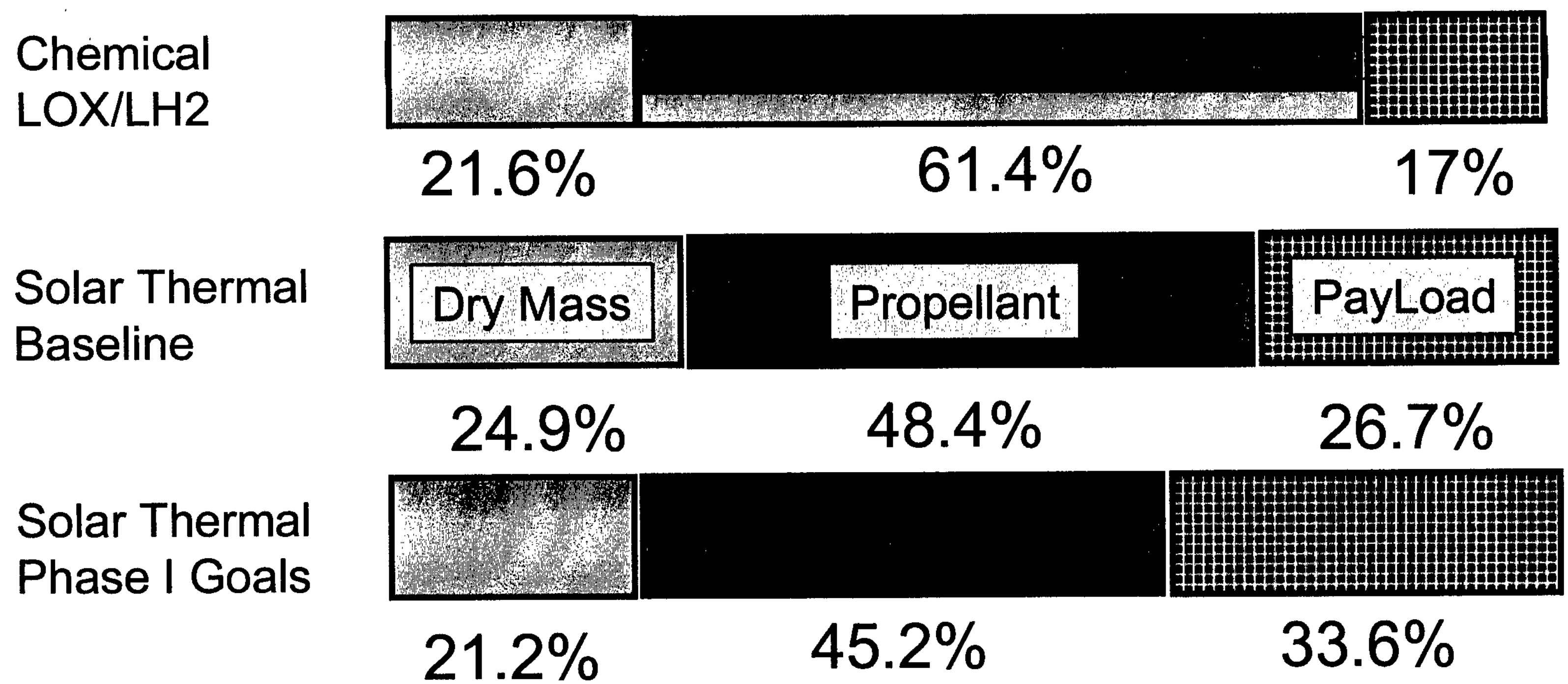
Baseline LEO Mass Ratio

48.4%	24.9%	26.7%
Propellant	Dry Mass	P/L

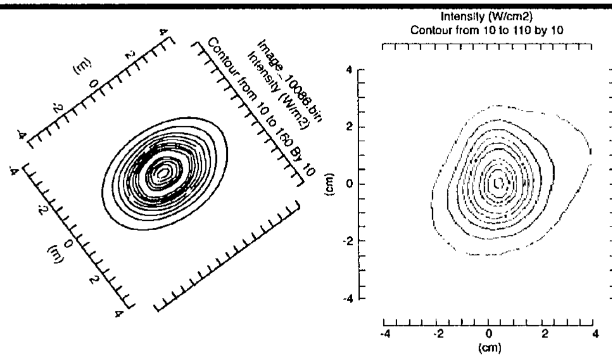
SOLAR THERMAL PHASE I PAYOFFS

Baseline is 57% increase over chemical

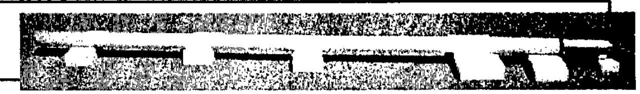
Phase I is 26% increase over baseline



Solar Thermal Propulsion Demonstration Approach



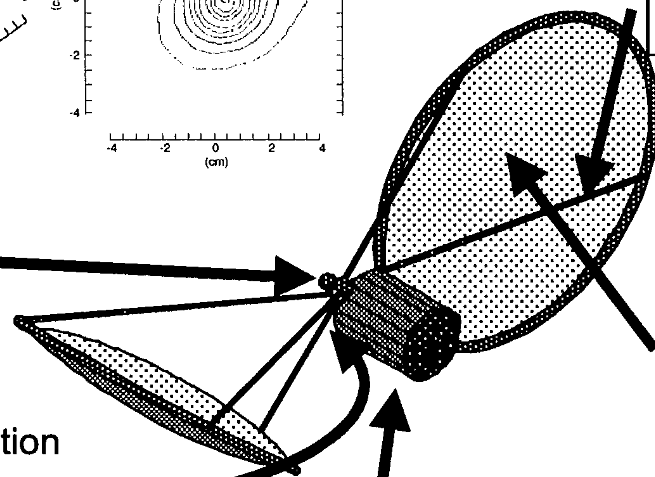
DIAGNOSTICS and MODELING
- Performance Check
- Design Tool
- Payoff Determination



THRUSTER

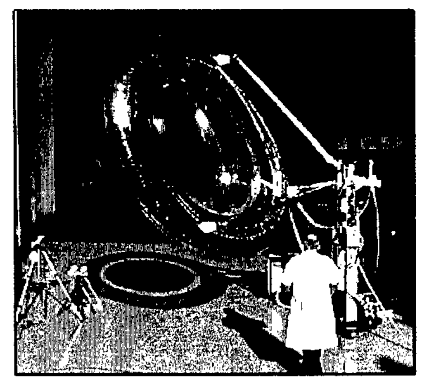
Optical wrap design
- 90% reduction in mass

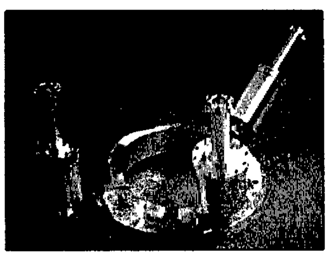
High temp moly secondary
- Significant reduction in contamination



CONCENTRATOR SUPPORTS

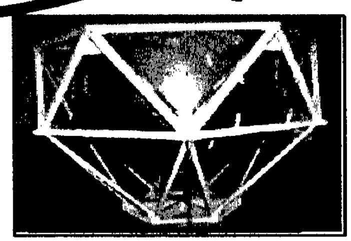
Deployable ridigizing struts
- 15% reduction in mass
- Enables compact packaging
- Reduces make-up inflatant





SUN-ACQUIRING, POINTING &TRACKING

Focus sensor and control
- Reduces bus ACS



CRYO LH2 TANK & FEED

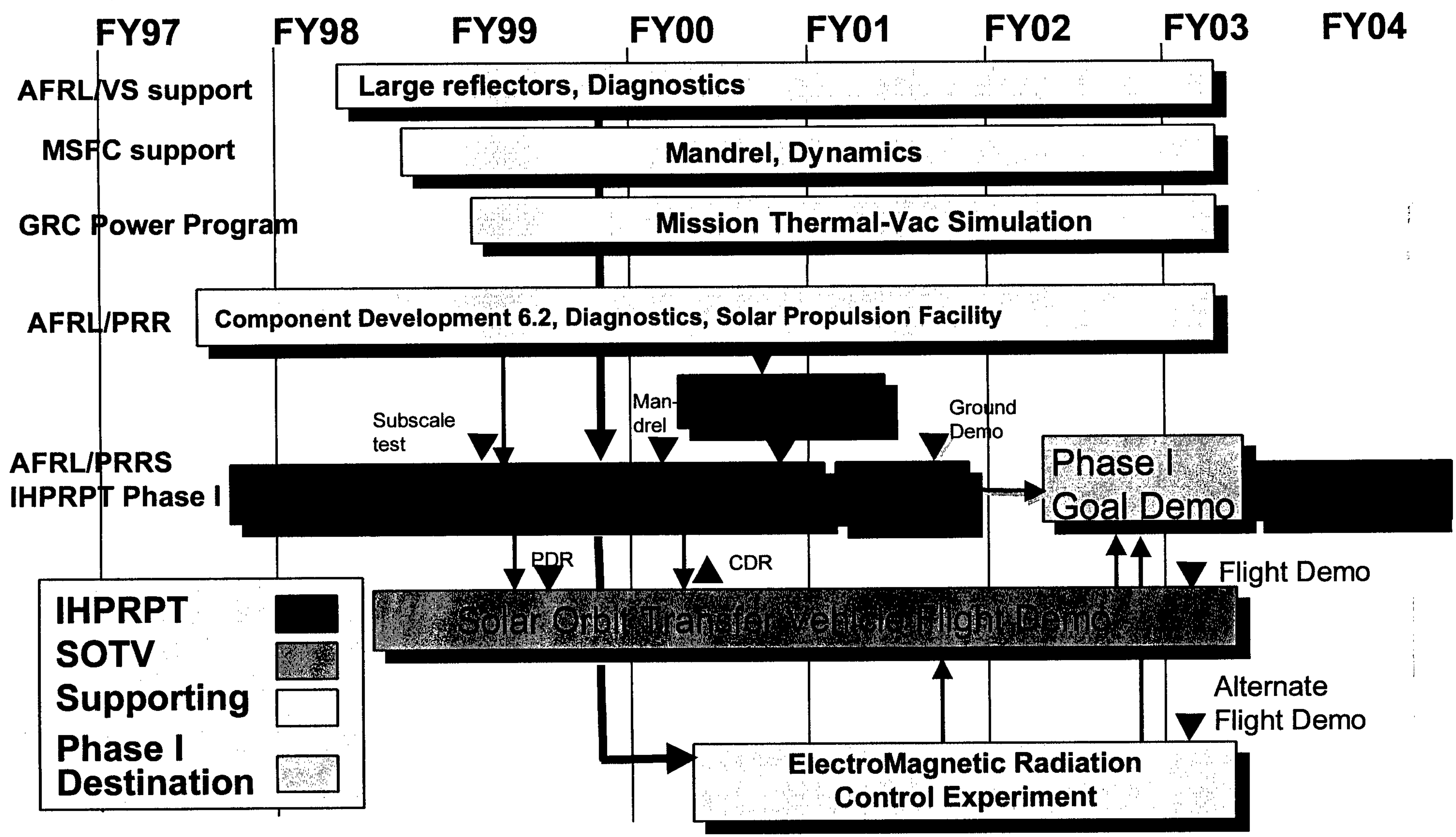
Selective Phase acquisition
- Reduces mass

Composite LH2 Tank
- Reduces mass

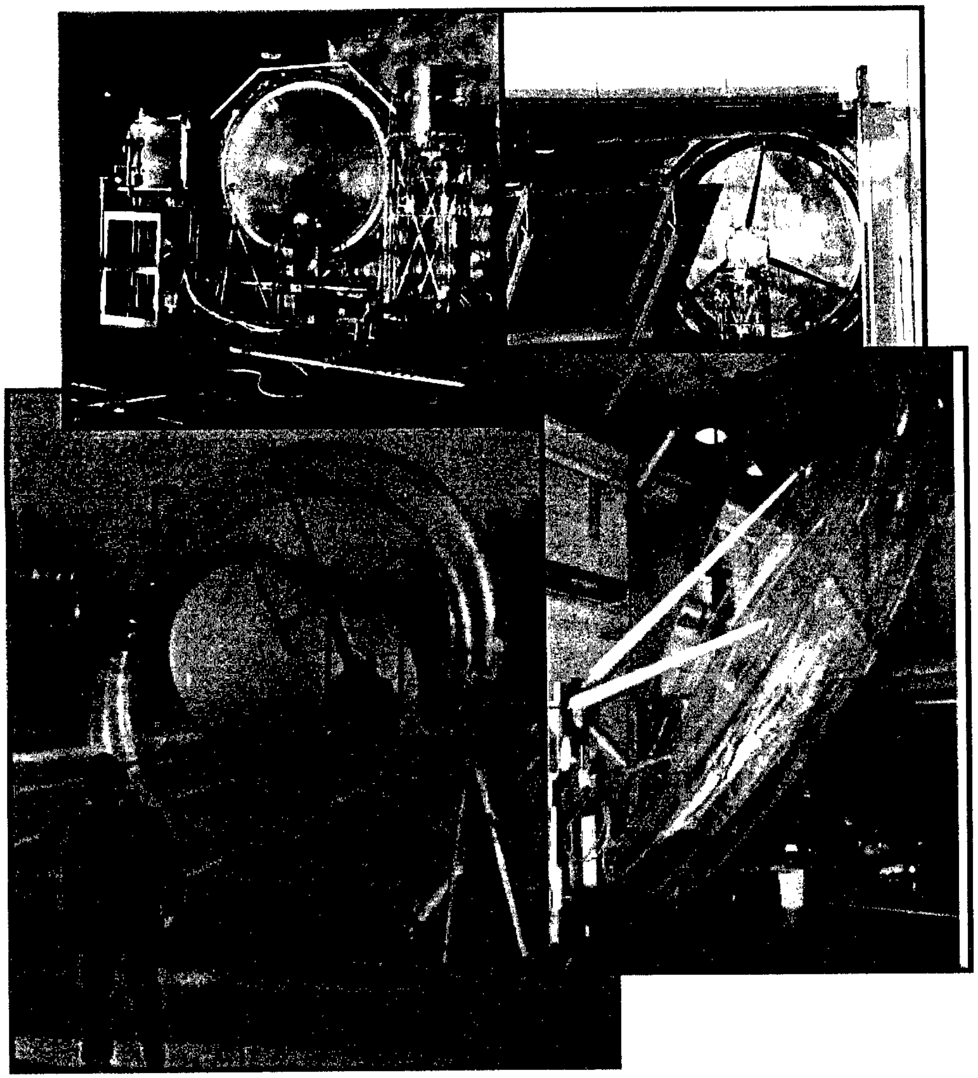
CONCENTRATOR

Thin Film Inflatable Concentrator
- 50% reduction in mass
- 95% reduction in packaged volume

IHPRPT PHASE I SOLAR ROADMAP

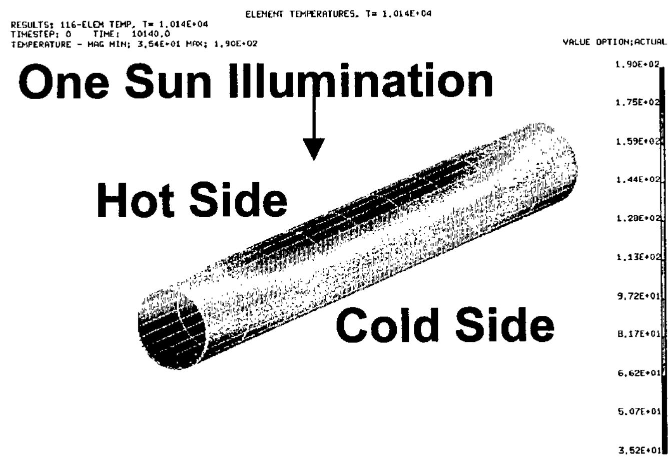


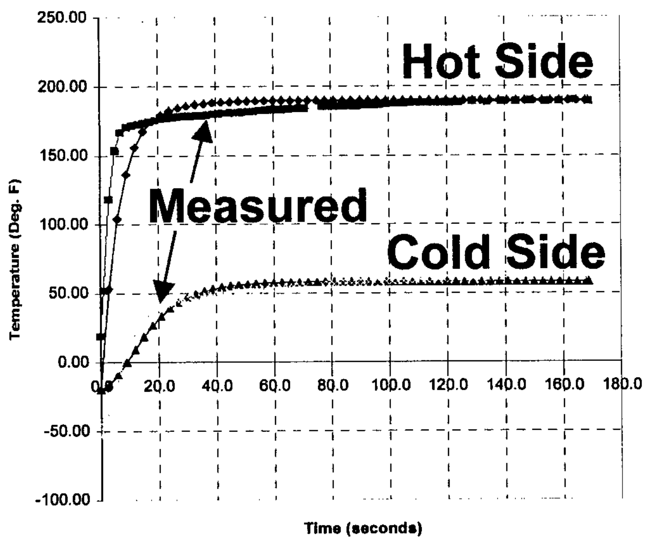
PHASE I GOAL DEMO INTEGRATED GROUND TEST OF THRUSTER AND CONCENTRATOR



- Concentrator will track sun
- Matches flux profile but not power of space system
- Thruster in vacuum chamber
- 792 sec Isp will be shown by analytical correction of:
  - 25% atmospheric loss
  - 10% window loss

Foam Rigidized Strut Thermo-Vac Modeling



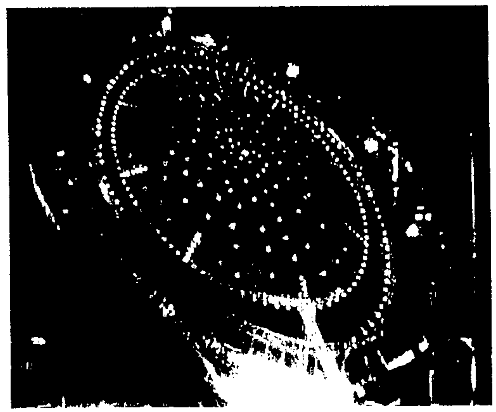


- Strut Illuminated in Vacuum
- Approximately One Sun
- Liquid Nitrogen Cold Walls
- Model and Measurement Match Closely (See Lower Left)
- Hot Side about 190 Fahrenheit
- Cold Side about 60 Fahrenheit
- Data to be Used in Structural & Dynamics Modeling

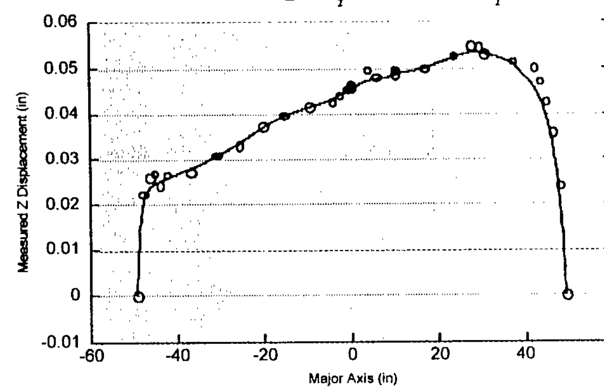
FEM Design Model Verification for TSC-6

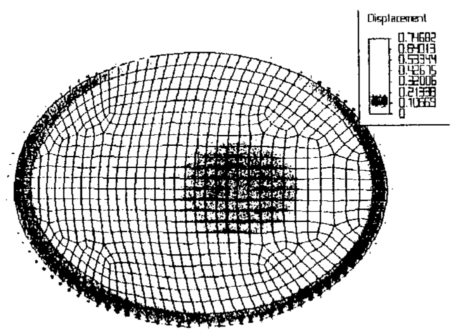
SOTV Solar Orbit Transfer Vehicle

- Used photogrammetry to measure TSC6 shape at varying pressures
- Created ALGOR model of TSC6 and measured shape change at varying pressures
- Conclusion: ALGOR model accurately defines TSC6 and may be used for optimization

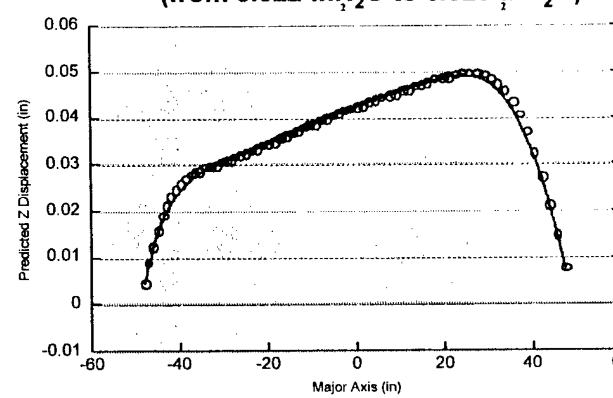


Photogrammetric Measurement of Shape Change (from 0.022-inH_2O to 0.025-inH_2O)





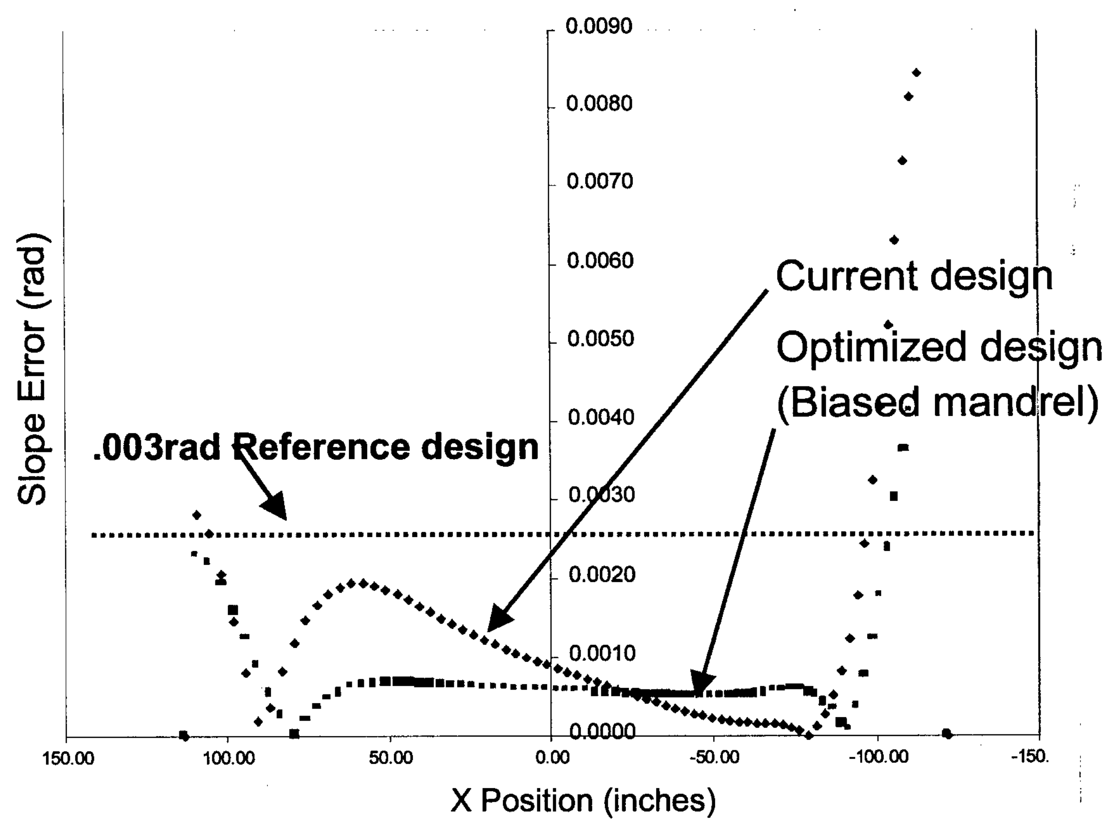
ALGOR Model of Shape Change (from 0.022-inH_2O to 0.025-inH_2O)



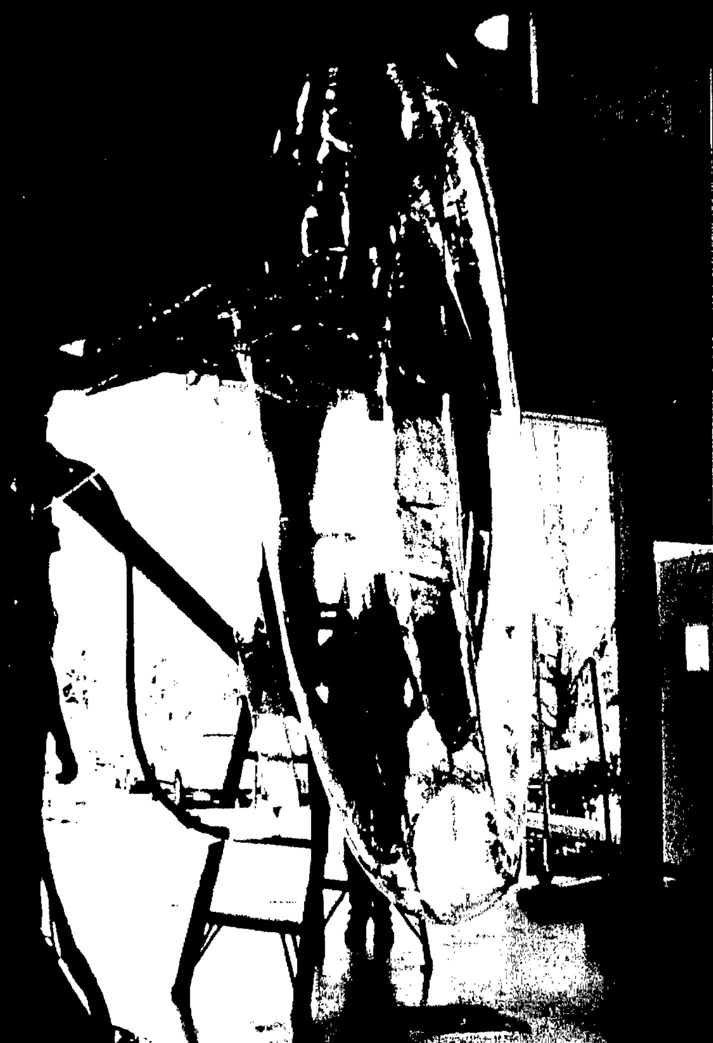
FSC Design Analysis

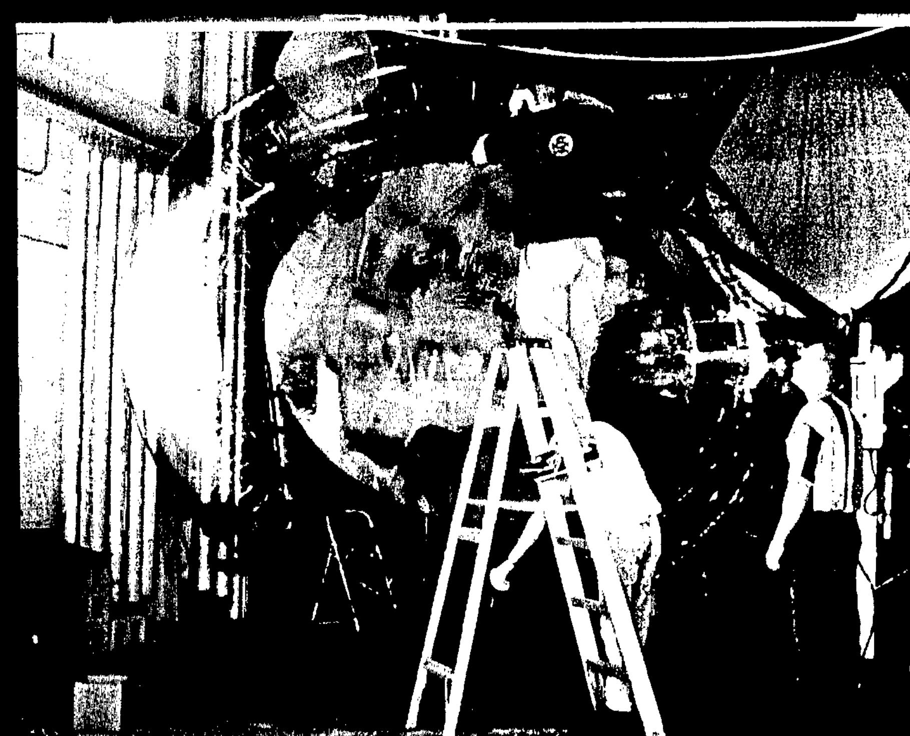
- Majority of reflector surface lies below 0.003 rad error
- FSC baseline design operates at lower pressures than those used in TSC6. The reflectivity of TSC6 indicates this is a viable design option.
- Initial shape optimization provides additional margin and improved slope error.
- Biased Mandrel 10% to 20% Greater Intensity and Power

FSC Slope Error Along Major Axis



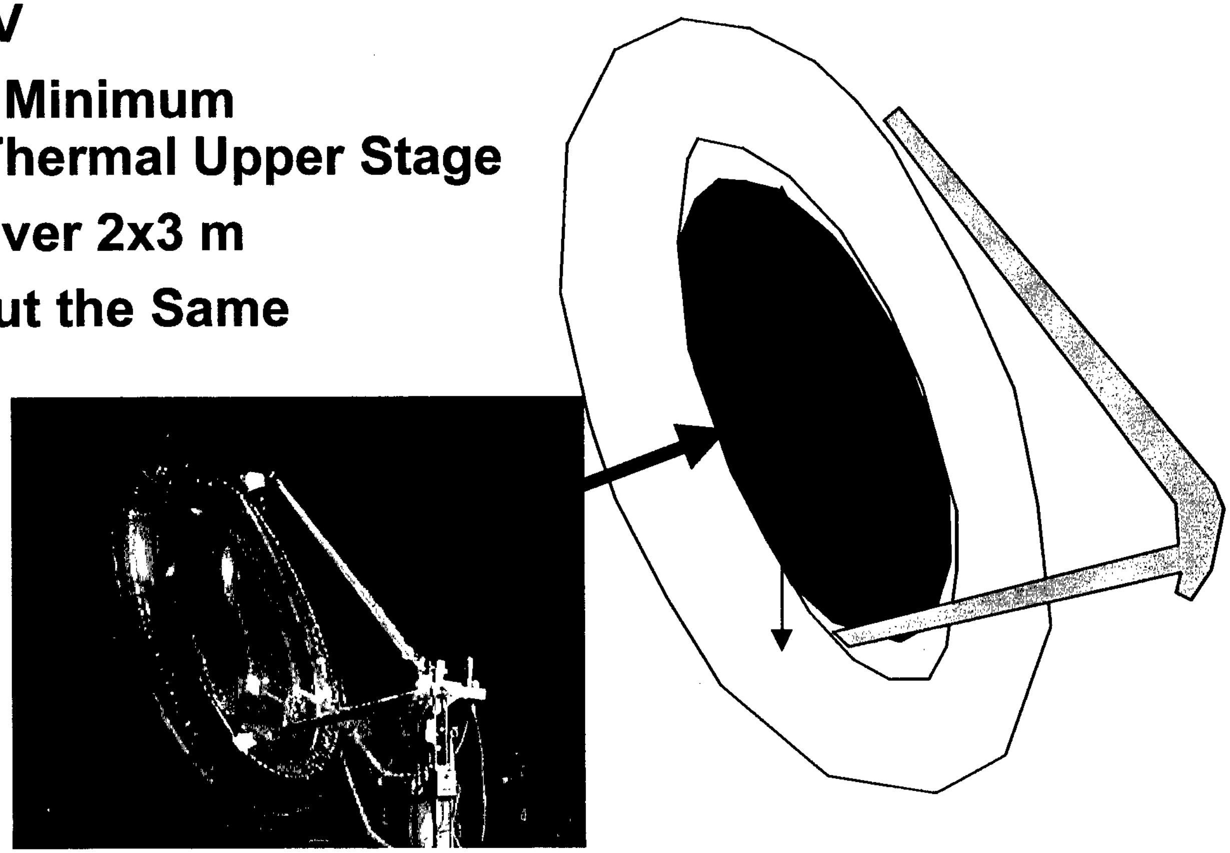
SRS Molded Off-Axis Concentrator





Flight Scale Reflector

- Fabrication Techniques From 2x3 m Concentrator
- About 4x6 m
- Flight Size for SOTV
- About Half Size for Minimum Operational Solar Thermal Upper Stage
- Quadruple Power over 2x3 m
- Peak Intensity About the Same

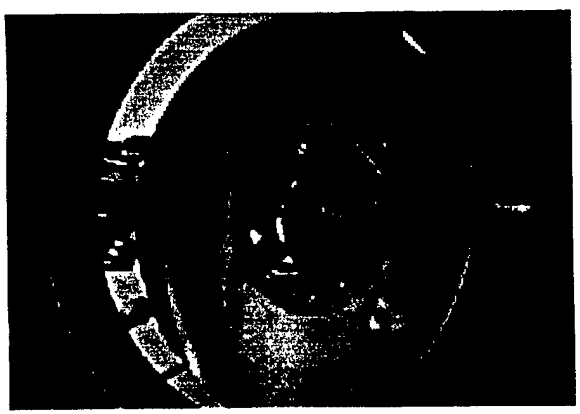


SRS Graphite Thruster
May 1, 1997

Front Side ~~Hub Camera~~

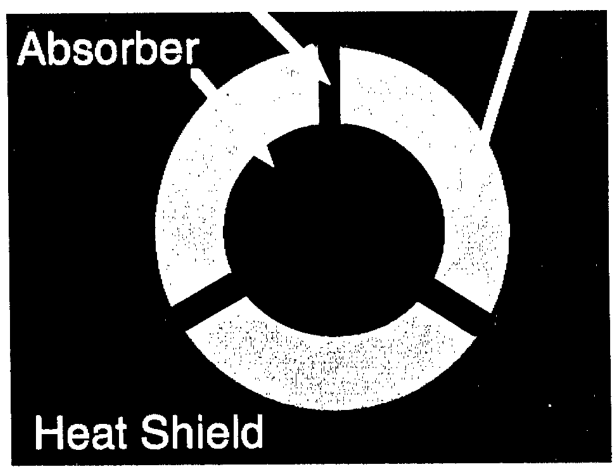
Back Side ~~Nozzle Camera~~

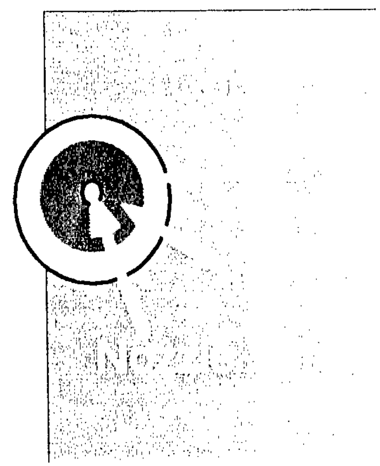
Partch 8/98

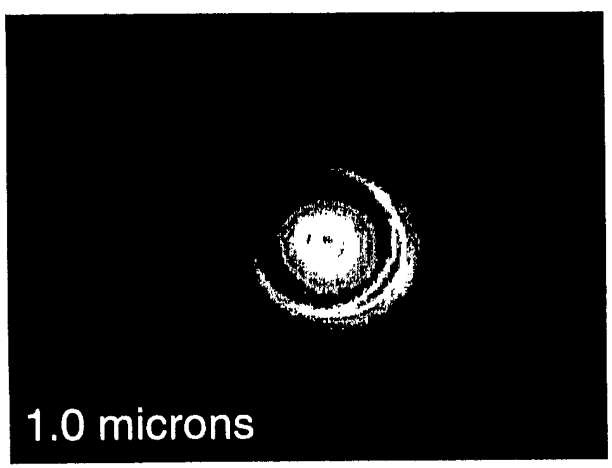


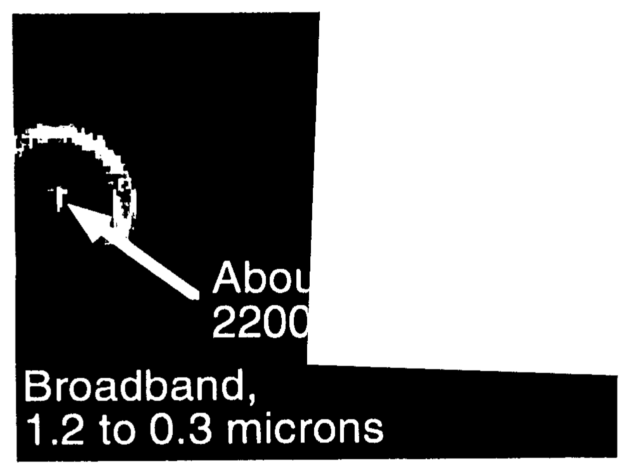
Support

Secondary Concentrator



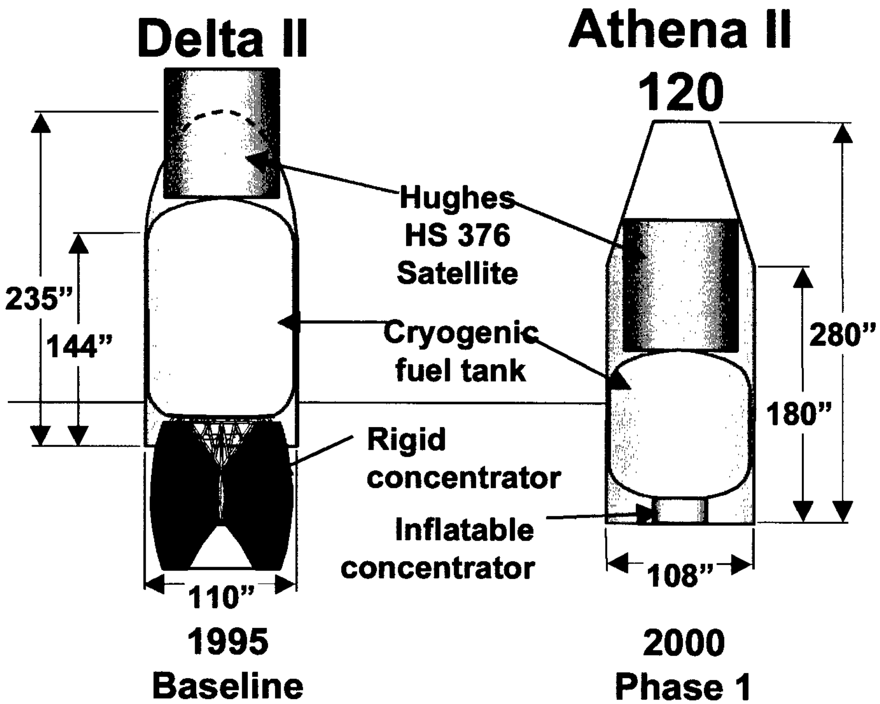




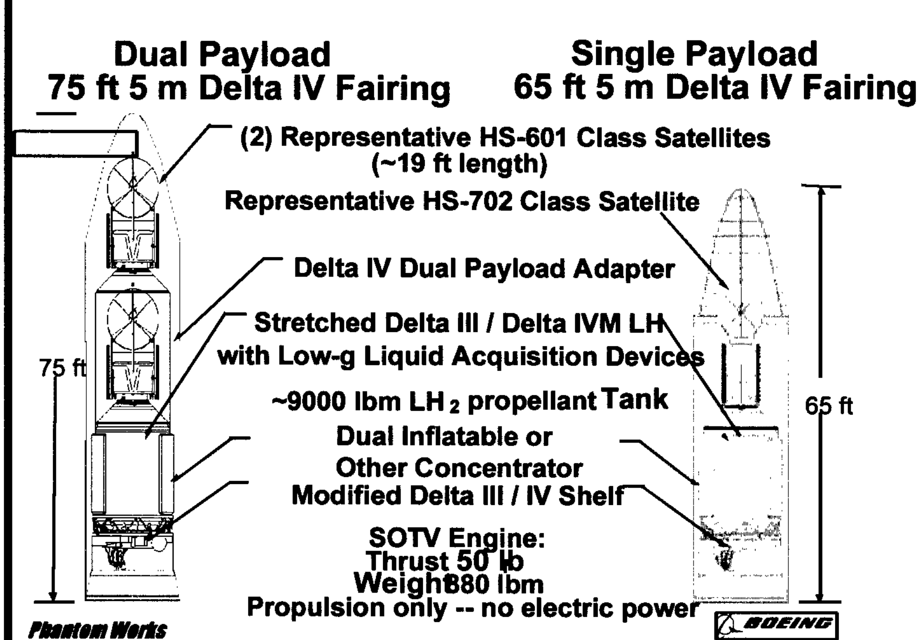


TECHNOLOGY TRANSITION OPPORTUNITIES

SOTV Packages Well on EELV/Delta IV and Athena

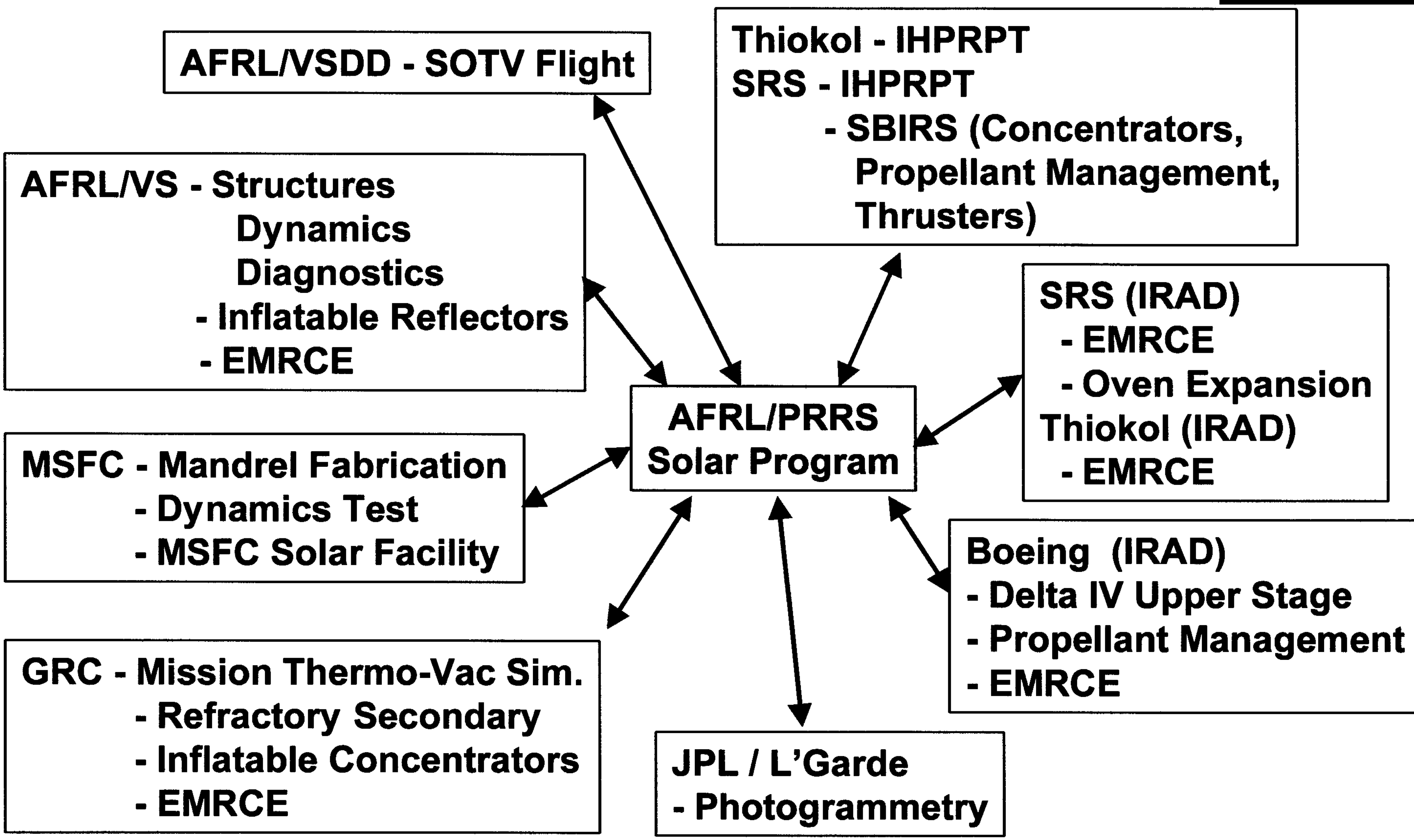


Thiokol analysis

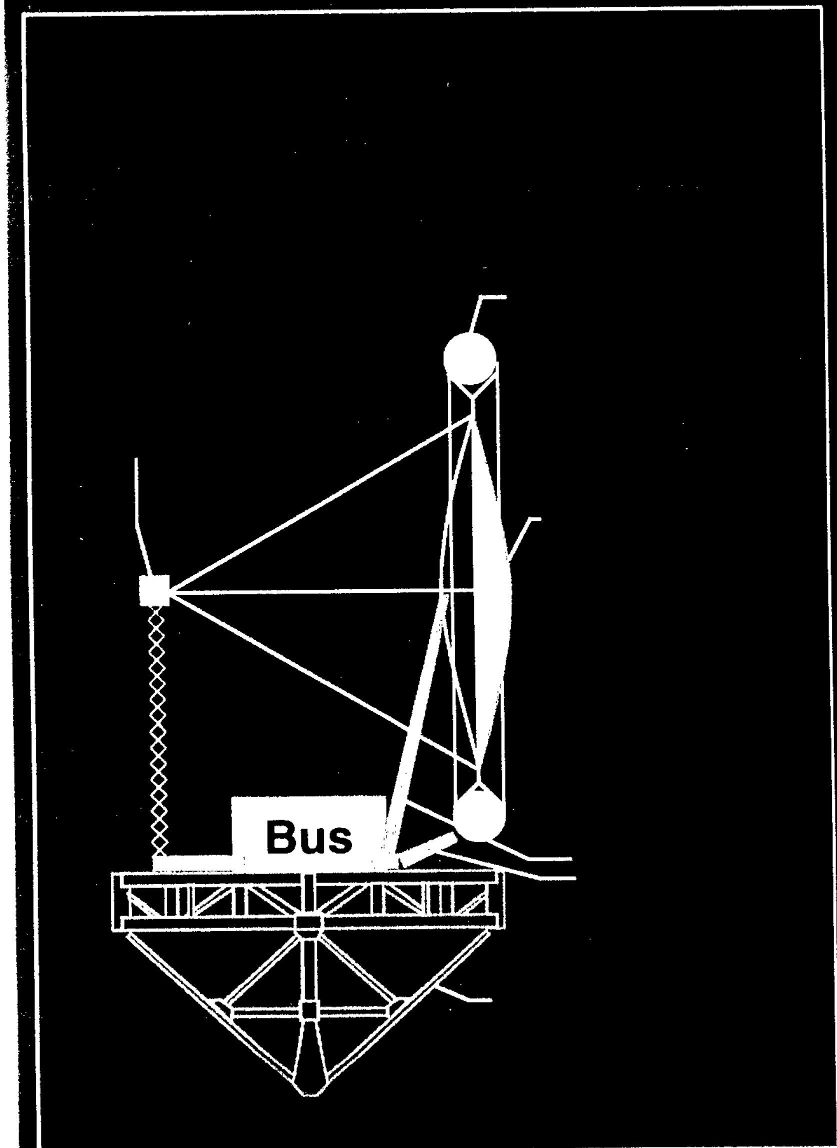


Boeing analysis

Solar Propulsion AFRL/PR Alliances



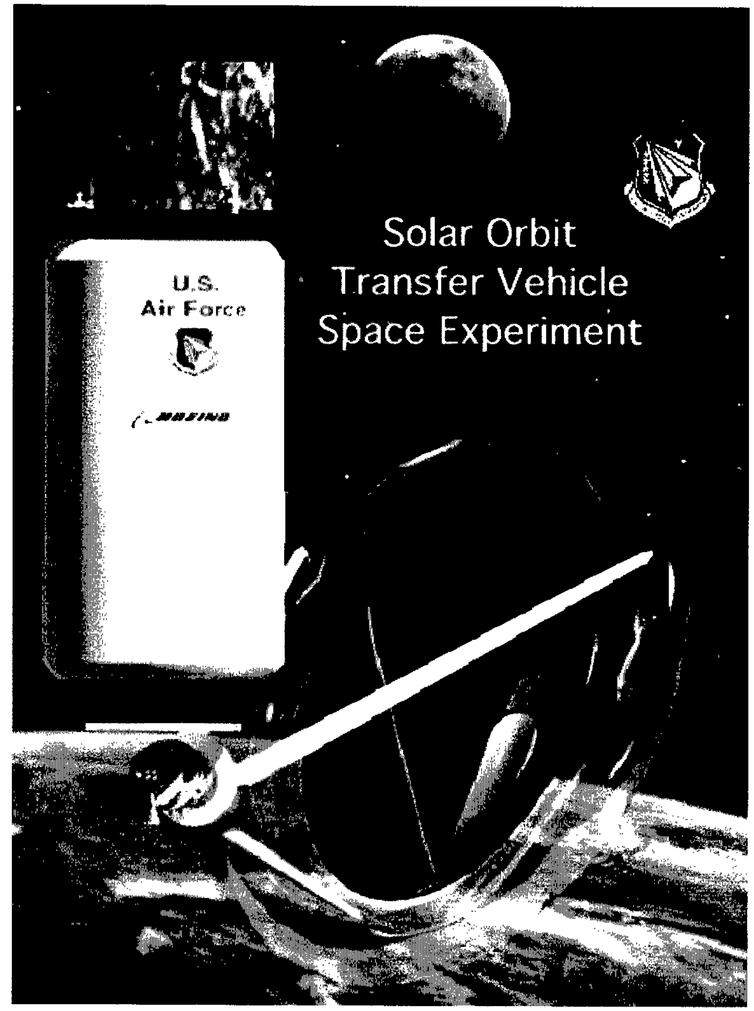
AFRL-910-ElectroMagnetic Radiation Control Experiment Concept



- Objective
  - Deploy Inflatable 5 Meter Antenna
  - Verify Precision Shape
  - Verify Focused Energy
  - Verify Diagnostic Techniques
- Description
  - 4.88 Meter CP1 Inflatable Parabolic Metalized Reflector
  - Diagnostics:
    Surface Accuracy, Surface Optical Properties, Coarse and Fine Pointing Accuracy, Overall Deployment and Operational Performance
  - Verify Thermal and Optical Models
  - Compare to Ground Tests
  - Represents Inflatables for Many Missions:
    Antennas, Radiometers, Heat Shields, Solar Concentrators for Power and Propulsion, Concentrators for PV Arrays, Solar Sails

PHASE I GOAL DEMO CONCENTRATOR OPERATION DEMONSTRATED ON SPACE FLIGHT

- System demonstration of SOTV concept
- Baselined IHPRPT concentrator
- Step toward advanced space vehicles
  - EOTV, ROTV, and SSV
- Demonstrated technologies
  - Multi-burn solar propulsion
  - 0-g inflatable solar concentrators
  - Thermal storage cavity absorber
  - 0-g thermionic power production
  - 0-g cryo H2 handling
  - Flight dynamics interaction
- SOTV Launch date and funding being addressed
- Back up space flight planning continuing



Conclusions

- Solar Thermal Propulsion

Payoff

Double Payload

Or

Double Delta V